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Wood Furniture Coating: Summary Report for Technical Support in Development of a Revised Ozone State Implementation Plan for Memphis, Tennessee

Pacific Environmental Services, Inc.
Durham, NC

Prepared for

Environmental Protection Agency, Atlanta, GA

Jun 85

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REPORT

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PACIFIC ENVIRONMENTAL SERVICES, INC.

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WOOD FURNITURE COATING

SUMMARY REPORT
FOR
TECHNICAL SUPPORT IN DEVELOPMENT
OF A REVISED OZONE STATE
IMPLEMENTATION PLAN FOR
MEMPHIS, TENNESSEE

Mr. Ron McHenry - Project Officer
U.S. Environmental Protection Agency
Region IV
EPA Contract No. 68-02-3887
Assignment No. 13

Pacific Environmental Services, Inc.
1905 Chapel Hill Road
Durham, North Carolina 27707

June 1985

DISCLAIMER

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The document presents information on emissions of volatile organic compounds (VOC) from wood furniture coating facilities in Shelby County, Tennessee. Information is presented on the industry, emissions from wood furniture coating facilities, emission control techniques, and the costs of reducing emissions. Sources of information include plant visits to furniture coating facilities in Shelby County, a review of Shelby County permit applications, the 1985 VOC emissions inventory for Shelby County, discussions with furniture coating facilities and spray equipment vendors, a review of technical literature, and studies conducted in other states. The control measures described in the document represent the presumptive norm or reasonably available control technology (RACT) that can be applied to existing furniture coating plants. It may require technology that has been applied to similar, but not necessarily identical, source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source.

KEYWORDS: *Wood products, *Furniture, *Coatings, *Air pollution control, *Volatile organic compounds, *State implementation plan.

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GLOSSARY

Air-assisted airless spray application	A method of coating application in which the coating is atomized in variable-shaped patterns (e.g., conical or oval) through an airless fluid nozzle, and atomization is assisted by pressurized air cap.
Airless spray application	A method of coating application in which the coating is atomized in a conical-shaped pattern through an airless fluid nozzle.
Application area	The area where the coating is applied by spraying, dipping, or rollcoating (flowcoating) techniques.
Body Stain	Coating applied to give wood color uniformity and develop wood grain and character.
Coating	Topcoat, sealer, filler, washcoat, toner, stain, or other material that is applied directly to the wood part or furniture.
Filler	Used to fill large pores in wood. Enables subsequent coating applications to achieve a smooth finish.
Glaze, shading stains, padding, spatter	Coating applied in small amounts, usually by hand, to highlight and give character to wood.
Sealer	Coating applied to seal wood for subsequent coatings.
Topcoat	Final coat applied to wood. Usually nitrocellulose lacquer to provide a clear, durable finish.

Transfer efficiency	Ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids used, expressed as a percentage.
Washcoat	Coating applied to seal wood surface, prevents subsequent unwanted staining from filler coat, and stiffens wood fibers for subsequent sanding.
Wood furniture	Room furnishings that include cabinets, tables, chairs, beds, sofas, shutters, art objects, and any other coated furnishings made of solid wood and/or wood composition and/or simulated wood material.

1.0 INTRODUCTION AND SUMMARY

This document presents information on emissions of volatile organic compounds (VOC) from wood furniture coating facilities in Shelby County, Tennessee. Information is presented on the industry, emissions from wood furniture coating facilities, emission control techniques, and the costs of reducing emissions. Sources of information include plant visits to furniture coating facilities in Shelby County, a review of Shelby County permit applications, the 1985 VOC emissions inventory for Shelby County, discussions with furniture coating facilities and spray equipment vendors, a review of technical literature, and studies conducted in other states.

The control measures described in this document represent the presumptive norm or reasonably available control technology (RACT) that can be applied to existing furniture coating plants. Reasonably available control technology is defined as the lowest emission limit that a particular source is capable of achieving by application of control technology that is reasonably available, considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical, source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. However, short-term evaluation programs are considered an appropriate technology-forcing aspect of RACT.

The VOC's emitted are predominantly solvents used in the formulation of coatings that are applied to wood furniture by spray or roller application. Emission reductions of between 30-35 percent can be achieved by changing from conventional air spray equipment to equipment such as air-assisted spray equipment. In addition, use of good engineering and housekeeping practices in coating and solvent handling can further reduce VOC emissions.

RACT includes requirements for application equipment and housekeeping procedures. The major provisions of the RACT recommendations are as follows:

1. The use of spray equipment with transfer efficiencies at least equivalent to those achieved by air-assisted airless spray equipment.

2. As an alternate, achievement of total emission reductions in affected coating application steps by other means (e.g., low solvent content coatings, high transfer efficiency application methods) equivalent to the requirement for air-assisted airless spray equipment.

3. The use of housekeeping and operation procedures that minimize VOC emissions from cleaning equipment, process lines, and waste materials.

These requirements can be met by use of process modifications and procedures that are considered to be demonstrated and reasonably available.

2.0 PROCESSES AND POLLUTANT EMISSIONS

2.1 INDUSTRY DESCRIPTION

Wood furniture coating involves the application of a series of protective or decorative coatings to wood surfaces. The wood furniture industry represents a large source of VOC emissions from surface coating operations, due primarily to very high volumes (airflow rates) of low solid coatings. The industry is composed of various market segments that are classified by Standard Industrial Classification (SIC) codes. A breakdown of nationwide establishments engaged in the manufacture of wood furniture is presented in Table 2-1 by their corresponding SIC codes.[1] The majority of wood furniture coating facilities are located in California, New York, Florida, and North Carolina. There are four furniture coating companies in Shelby County, Tennessee. Table 2-2 lists these companies and their major products.

One traditional aspect of the wood furniture industry is that it employs a relatively large number of people (labor intensive,) most of whom are unskilled. This dependency on unskilled labor may cause the industry difficulty in adopting new technology.

2.2 PROCESS DESCRIPTION

Wood furniture coatings are applied in a series of steps.[1] There is great variety in the number and complexity of coating steps that may be applied, but the basic steps are as follows: body stain; washcoat; filler; sealer; glaze, shading stains, padding, spatter; and topcoat.

The number and type of coatings applied to the wood depend on the quality of finish desired. Generally, the wood parts are transferred to each step in the process by means of a conveyor line. The wood pieces are coated in a sequential order by either spray equipment or roller coating equipment. Process lines may also contain drying ovens immediately after a coating is applied. The following subsections provide a brief description of roller coating and spray booth operations.

2.2.1 Roller Coating

Roller coating may be used to finish flat wood parts on various process lines, such as ink printing which is generally used to antique

Table 2-1. WOOD FURNITURE INDUSTRY [1]

SIC CODE	INDUSTRY	TYPICAL PRODUCTS	NUMBER OF ESTABLISHMENTS			
			Small	Medium	Large	Total
2434	Wood Kitchen Cabinets	Cabinets to be built-in Cabinets, factory made Vanities, bathroom and other	1,547	129	10	1,686
2511	Wood Household Furniture except Upholstered	Beds, boockcases, buffets chairs, chests, coffee tables, cradles, cribs, dressers, rockers, secretaries, stools, tables	1,444	307	116	1,867
2512	Wood Household Furniture Upholstered	Chairs, couches, davenports, living room furniture, rockers, sofas	865	310	59	1,234
2517	Wood Television, Radios, Phonograph and Sewing Machine Cabinets	Phonograph cabinets and cases, radio cabinets and cases, sewing machine cabinets and cases, stereo cabinets, television cabinets				
2521	Wood Office Furniture	Benches, bookcases, cabinets, chairs, desks, filing boxes, furniture, stools, tables	47	17	8	72
2531	Public Building and Related Furniture	Benches, blackboards, bleachers, chairs, church furniture, seats	280	85	12	377
		TOTAL	4,369	894	214	5,477

* By employment size: small = 1 to 49 employees; medium = 50 to 249 employees; large = 250 or more employees.

TABLE 2-2. MEMPHIS-SHELBY COUNTY FURNITURE MANUFACTURING[2]

Manufacturer	Major Products	Type of Coating
Aeolian Pianos, Inc.	Pianos, Piano Benches	Spray Coating
The Davis Company	Wooden Chairs	Spray Coating
Harts Manufacturing Company	Wooden Bedroom Furniture	Spray and Roller Coating, Ink Printing
Memphis Furniture Manufacturing, Ltd.	Wooden Bedroom Furniture, Wooden Desks	Spray and Roller Coating, Ink Printing

or "streak" wood parts. The print line may consist of a series of roll coaters, drying ovens, and ink print machines. Print lines can be divided into a sequence of coating operations, such as (1) base coat primer; (2) second base coat; (3) first seal coat; (4) printing; (5) second seal coat. First, flat wood parts are conveyed through a roll coater (see Figure 2-1) to apply a base coat primer, and then they are conveyed to a drying oven. Next, wood parts may receive another base coat from a roll coater, before entering a second drying oven. The wood parts may be conveyed into another roll coater where a sealer is added, then to a third drying oven. The wood may then go through a series of "antiquing" units, which add ink to the wood, and then to a roll coater for another seal coat. The wood may then be conveyed through a final drying oven and cooling system. After printing, the wood parts may be transferred to storage or to spray booths if further finishing is required.

2.2.2 Spray Coating

There are many spray application techniques available and presently in use in the wood furniture coating industry. Using conventional techniques such as air spray equipment, coating material is maintained under pressure in an agitated holding tank (shown in Figure 2-3). The material is fed through piping and flexible hoses to spray guns using air to atomize the liquid coating material by direct contact in a spray pattern. Air spray equipment is used typically in furniture manufacturing facilities in Shelby County. Spray coating usually occurs in a sequence of applications, which may include (1) toner coat; (2) wash coat; (3) stain; (4) sealer; (5) first lacquer; and (6) second lacquer (topcoat). Toner is applied to give the wood color. Lacquers are added in one, two, or three coats to finish the wood. A typical process line will have separate spray booths for each coating operation. Each spray booth has one or more manually operated spray guns. The wood is either manually carried to each booth or by means of an overhead or roller conveyor, which moves the wood to either the next spray booth or to an oven for quicker drying. Ovens are used to flash off and dry solvent but not to cure the coating. Figure 2-2 is a schematic drawing of a typical spray line. Spray booths (Figure 2-3) generally measure anywhere from 2.5 meters (width) x 2.5 x 2.5 (8 ft x 8 ft x 8 ft) to 6 meters (width) x 3 x 2.5 (20 ft x 10 ft x 8 ft), but they may be larger.

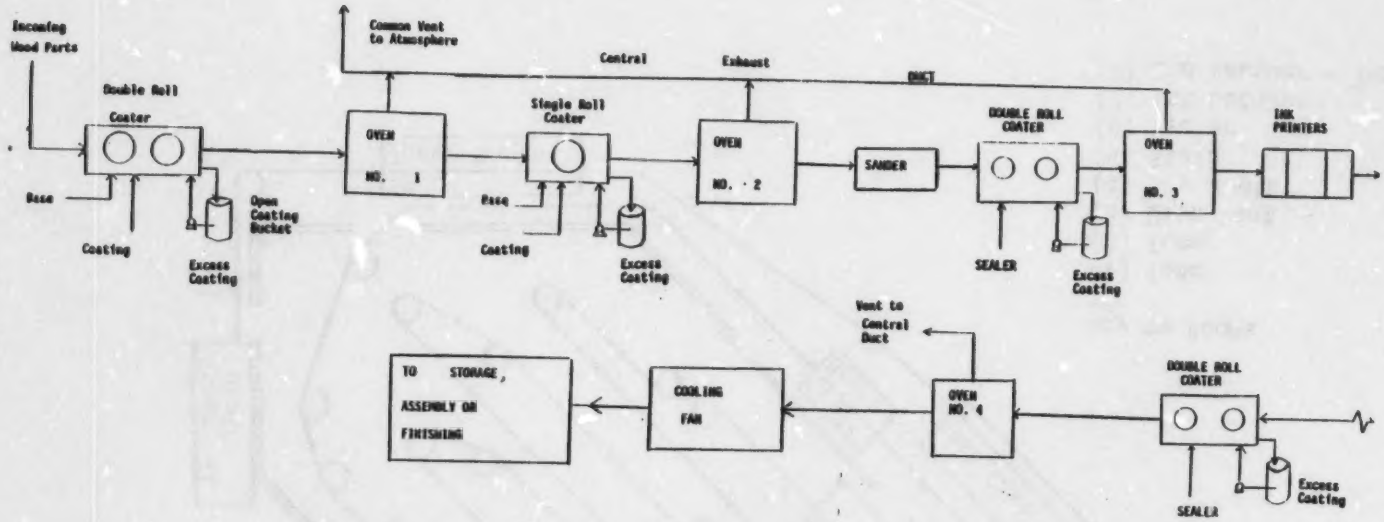

Figure 2-1. Schematic Drawing of a Roll Coating Operation (ink printing)[3].

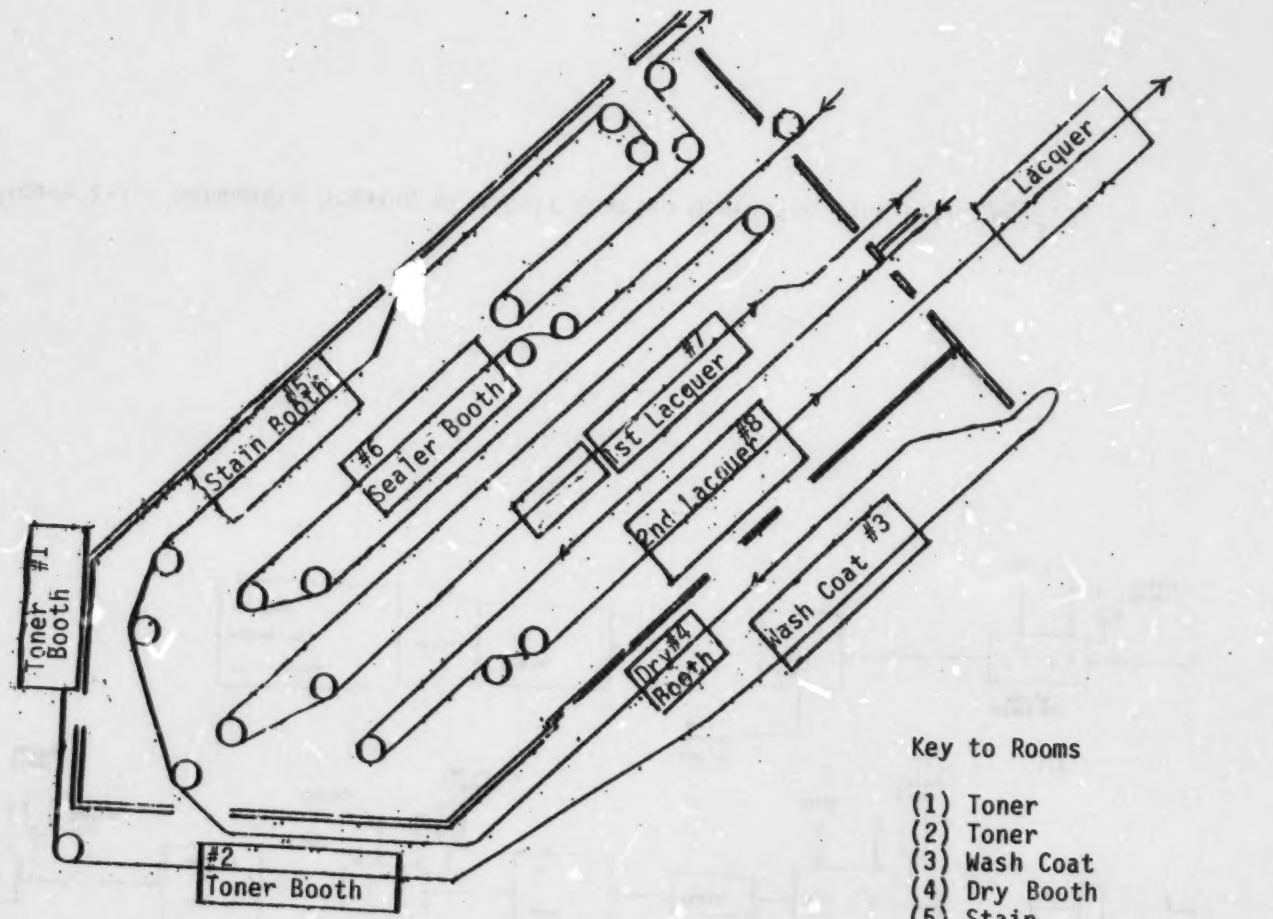

Figure 2-2. Schematic drawing of a typical spray coating line.[3]

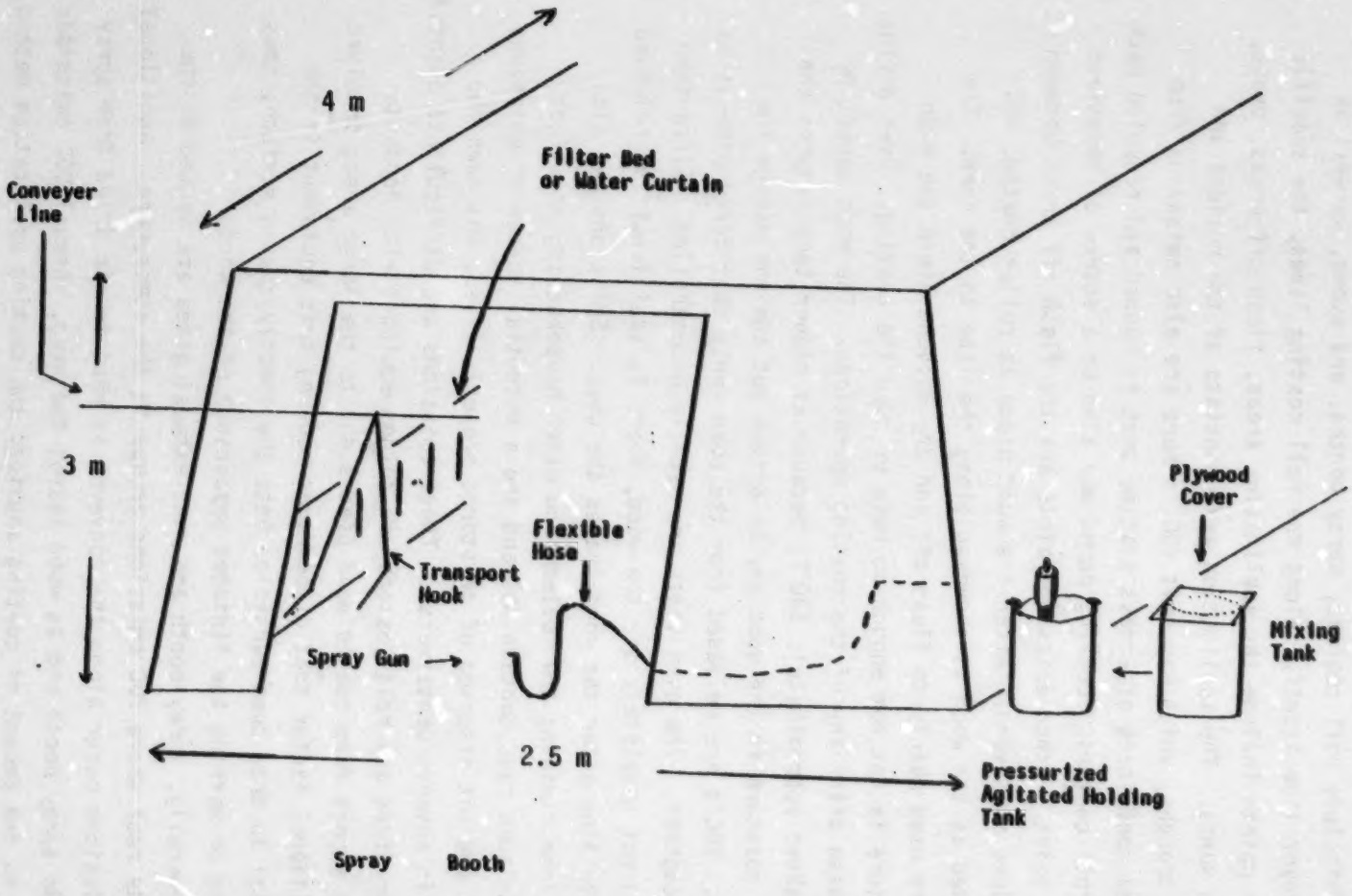

Figure 2-3. Schematic drawing of a typical spray booth,[3] (not to scale)

2.3 SOURCES OF VOC EMISSIONS

Potential sources of VOC emissions in the wood furniture coating industry include roll coaters, spray booths, and ovens, as well as the conveyor line itself. Along the roll coating lines, the specific emission points include the application areas, flash off areas, ovens, and oven vents. The application area consists of the rollers and coating troughs, which may emit VOC. There are also emissions from uncovered containers of excess coating that is pumped and recycled back to the roll coaters. Leaking pumps may also be a source of emissions at this point. Other emission points are the flash off areas between the rollers and ovens. After the wood piece is roller coated, VOC is emitted as the wood is conveyed along the line to the oven. The ovens are used mainly to flash off and dry solvent since the oven temperature is not hot enough to bake or cure the coating. Oven drying may be used after any of the coating operations. The wood cannot be heated above approximately 130°F, because at higher temperatures the natural moisture in the wood may be driven out and may damage the coating. VOC's are released from the oven vents that carry exhaust to the atmosphere. The oven vents are usually uncontrolled. Since the ovens do not completely dry the wood, there is additional VOC released along the line after the wood leaves the oven. Emissions may also result from cleaning the rollers and other housekeeping practices. Solvent-laden rags contain VOC and are a potential source of emissions if they are not disposed of or stored properly (i.e., wet down and placed in covered containers). These emissions are difficult to quantify. Conveyor lines and roll coaters are seldom equipped with hoods to capture vapors from coated wood pieces due to the large areas involved. An additional factor that discourages hooding this equipment is the potential to draw dust particles onto the freshly coated surface, thus imparing or marring the finished appearance of the wood.

Generally, spray booth and oven exhaust gases are vented to the facility roof where VOC emissions escape to the atmosphere. Additional VOC emissions occur along the conveyor as wood is air dried from spray booth to spray booth and as wood leaves the oven. Annual VOC emissions depend on the amount of coating applied, the coating application method,

and the VOC content of the coating, which may vary between 60 percent and 98 percent by volume. Additional emissions result from routine practices (e.g., equipment leaks, waste disposal, and clean-up procedures).

2.4 MODEL PLANTS

Two model plants were developed to characterize "typical" wood furniture coating facilities in Shelby County, Tennessee. The model plants are based on the use of organic coatings and spray booths that are equipped with conventional air spray systems. Model Plant A, which represents a medium-sized wood furniture facility in Shelby County, consists of six spray booths and uses a total of 340,000 liters (90,000 gallons) of coating annually. Model Plant B, which represents a large wood furniture facility, consists of twelve spray booths and uses a total of 680,000 liters (180,000 gallons) of coating annually. These hypothetical model plants reflect the range of wood furniture coating facilities in Shelby County. Tables 4-1 and 4-2 give the types of coating applied by Model Plants A and B, respectively. The model plants are used to estimate the environmental, economic, and energy impacts associated with RACT. The actual number of spray booths per plant ranges from 2 to about 20, and annual usage of coatings and solvents ranges from about 76,000 liters (20,000 gallons) to about 760,000 liters (200,000 gallons).[2,4] Roll coating operations are not reflected in the model plants because there is no reasonably available technique for controlling VOC emissions from these sources beyond good engineering and housekeeping practices (e.g., fix leaking pumps, cover container of coating).

2.5 REFERENCES

1. Control Techniques Guidelines for the Control of Volatile Organic Emissions from Wood Furniture Coating. Draft Document. U.S. Environmental Protection Agency, Emission Standards and Engineering Division, Chemical and Petroleum Branch, Research Triangle Park, NC. April 1979.

2. Memphis-Shelby County Point Source Emissions Inventory, 1985. Memphis-Shelby County Health Department, Pollution Control Section, Memphis, Tennessee.

3. Memorandum from T.W. Rhoads and D.G. Cole, Pacific Environmental Services, Inc., to J.R. McHenry, U.S. Environmental Protection Agency, Region IV. Trip Report - Memphis Furniture Manufacturing Company, Memphis, Tennessee. March 1985.

4. Permit application process and surface coating emissions data. Memphis and Shelby County Health Department, Air Pollution Control Section. Memphis, Tennessee.

3.0 EMISSION CONTROL TECHNIQUES

VOC emissions from the furniture coating industry can be reduced primarily by application method changes. In addition, low VOC content coatings are currently in place but are not in widespread use. For the reasons discussed in this chapter, add-on control devices, such as incineration or carbon adsorbers, are not considered to be feasible emission control techniques for the wood furniture coating industry.

Section 3.1 of this chapter discusses reformulated coatings, or use of low VOC coatings, while Section 3.2 discusses application method changes. Section 3.3 discusses add-on control techniques.

3.1 REFORMULATED COATINGS

VOC emissions can be reduced by use of low VOC or water-based coatings. These coatings are based on water-reducible acrylic resins, but some water-reducible nitrocellulose film formulations have been developed. Every industrial formulation is customized and, therefore, is different. Most of these coatings, however, have a VOC content of up to 7 percent. Water-based coatings have been used successfully on military aircraft in combination with air or airless spray equipment, and studies have shown the performance and application of these coatings to be acceptable[1,2]. These studies have also identified advantages and disadvantages of the use of water-based coatings. A major advantage is that, in addition to the reduced VOC content, there is a higher transfer efficiency and reduced emissions.[1,3] Cleanup and thinning of coatings is with water, which therefore reduces the use of costly organic-based cleaning solvents. In addition, the use of water reduces employee exposure to VOC fumes and decreases the fire hazard present when organic-based coatings are used. The water-based primer has also been found to have better adhesion. A main disadvantage found in aircraft coating has been a shorter "pot life" of the water-based coating as compared to the solvent-based coating. (Pot life refers to the amount of time the mixture is usable without stirring.) This may not be relevant to the wood coating industry if coating moves rapidly through a delivery system. In

addition, plant operators have complained of longer drying times and freezing problems in outdoor storage for water-based coatings. However, water-based paints may contain polyethylene glycol (anti-freeze) or utilize indoor storage to avoid this problem. Additionally, Memphis has a relatively warm climate with few days in which freezing would be a problem. The most significant disadvantage is that unless the water evaporates uniformly, a curded appearance is obtained. This is of particular importance to the furniture industry because finish quality is a critical factor in customer selection. For this reason primarily, the furniture industry has been reluctant to adopt water-based coatings for production. However, this does not preclude widespread use of low VOC coatings in the future, particularly as improvements are made in terms of achieving a high quality finish. At present, the U.S. Army has purchased furniture that will be sprayed in Germany with a low solvent coating that reduces emissions by about 60 percent. In addition, at least one company in Shelby County is experimenting with low VOC coatings. Plant owners and operators may find it more desirable to reformulate coatings than to change the coating application methods.

3.2 APPLICATION METHODS

The quantity of VOC emissions from surface coating operations depends on the amount of coating applied, the coating application method, and the coating VOC content, which was discussed in Section 3.1. VOC emission reductions may be achieved through use of low VOC coating or through implementation of improved application methods. Furniture coating application methods may be divided into two categories: (1) roller coating and (2) spray coating.

3.2.1 Roller Coating

Roller coating utilizes immersed roll bars to apply finish to flat wood pieces with a very high (70 percent) tranfer efficiency. VOC emissions occur from several points along the process line as discussed in Section 2.3. Emissions from the application and flash off areas (roll coaters and conveyor line) cannot be easily controlled because loading or bagging these areas would not be practicable. Emissions from coating containers located near the roll coaters can be controlled by covering them, and pumps used to transfer coating from these containers

back to roll coaters should be checked periodically for leaks. Any leaks detected should be repaired as soon as practicable. Emissions from equipment cleanup can be controlled by good housekeeping practices, such as wetting down rags and placing them in closed containers. As discussed in Section 3.3, it is not economically feasible to apply conventional add-on VOC control methods for reducing emissions from ovens and roll coaters (e.g., ducting the exhaust to a catalytic or thermal incinerator) because of the high cost associated with installation and operation of a vent system.

3.2.2 Spray Coating

Spray coating equipment includes air spray, airless spray, air-assisted airless spray, and various forms of electrostatic spray systems. All of these spray coating methods may utilize heat to increase the temperature of the coating. This decreases the viscosity of the coating (i.e., thins the coating out). This increases the transfer efficiency of the coating method because it lowers the amount of coating necessary to cover an equivalent wood surface area. Spray coating equipment is discussed in the following subsection.

3.2.2.1 Air Spray, Airless, and Air-Assisted Spray Equipment. Air spray is the most common spray application method in the wood furniture industry. The air spray produces a fine finish, but due to the amount of air used, there is quite a bit of turbulence generated in the spray pattern. This turbulence causes excessive "overspray" and a relatively low transfer efficiency (i.e., a low ratio of the amount of material deposited on a surface being painted to the amount of material applied at the spray gun). Figure 3-1 presents a drawing of a typical air spray gun. Airless spray minimizes overspray, and therefore results in coating savings, but the particles are coarse and do not produce a desirable finish. The air-assisted airless spray is designed to eliminate "tailings" and has a 30-35 percent better transfer efficiency than air spray. The basic concept of airless spray is to minimize overspray and improve transfer efficiency of conventional air spray nozzles. Airless spray uses hydrostatic pressure to force material through a small orifice to accomplish atomization of coating particles. The degree of atomization is dependent on both the fluid pressure and the size of the orifice. The greater the degree of atomization, the more controllable

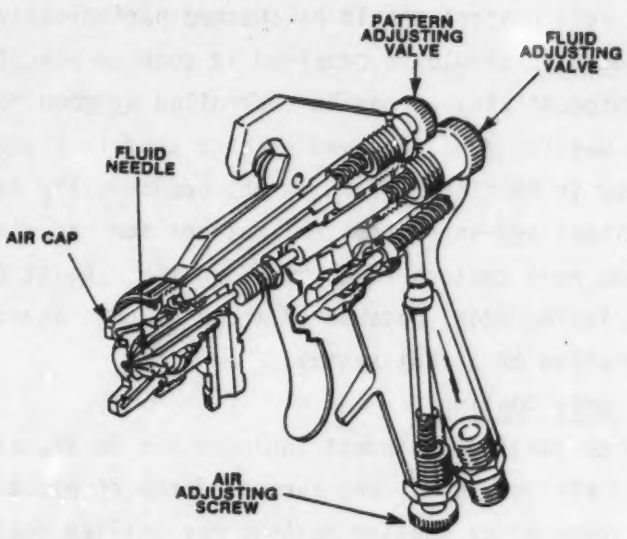

Figure 3-1. Typical air spray gun (Reference 3-11).

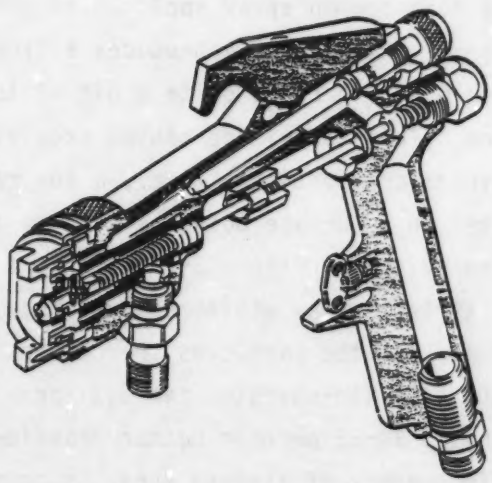

Figure 3-2. Typical air-assisted airless spray gun (Reference 3-4).

and uniform the fluid spray pattern. In general, effective atomization occurs only at higher fluid pressures (greater than 69 Pa (1,000 psi)).

Air-assisted airless spray utilizes a small amount of air (30 - 80 l (1 - 3 cfm)) of low pressure (0.7 - 2.1 P (10 - 3 psi)) to increase atomization of the spray particles and control the spray pattern. This enables a corresponding reduction in fluid spray pressure and results in a softer, more controllable spray pattern, which reduces overspray and increases transfer efficiency, thereby saving coating materials. Figure 3-2 represents a typical air-assisted airless spray gun. Table 3-1 shows the characteristics of the various spray techniques and their transfer efficiencies (excluding the electrostatic technique). Transfer efficiencies given in Table 3-1 reflect a general industry consensus for wood furniture coating.[8,9]

3.2.2.2 Electrostatic Spray Application. The electrostatic spray application method electrostatically atomizes coating particles and imparts a negative charge to them. It uses a rotating disc to force the particles in an outward radiating circle. Electrostatic forces concentrate the coating particles into a small area with very little overspray. Wood will generally contain enough moisture to concentrate the particles, and commercial sensitizing materials can treat the wood if necessary.

The transfer efficiency of electrostatic equipment depends on many factors, including humidity and temperature of the workroom, particle size and particle conductivity (or resistivity). Under ideal conditions, the transfer efficiency can exceed 95 percent which is considerably higher than other spray equipment;[5] however, most systems operate at about 85-90 percent.[6]

In general, the industry has found that a detailed research and development program is helpful to make the electrostatic spray application method work effectively. This effort may require a moderate capital outlay, before a system can be assembled, which includes some revamping of the existing system. The capital cost of a thoroughly computerized and automated system may run as high as $156,000 per booth containing four spray nozzles or "bells".[6] This cost has discouraged some facilities from pursuing electrostatic spray systems, in favor of airless systems, which are simpler and less costly.[6] However,

Table 3-1. Characteristics of Various Spraying Equipment[4]

	Air Spray	Airless Spray	Air-Assisted Airless Spray
1. Finish Appearance	Fine	Coarse	Good
2. Transfer Efficiency[a]	Low	16-20 % better than air spray	30-35% better than air spray
3. Fluid Flow Control	Limited to very low to medium flow rate, usually 30 fl oz/min.	Limited to high and very high flow rate, normally over 25 fl oz/min.	Wide range of flow rate: normally from 5 fl oz/min. to over 50 fl oz/min.
4. Booth Maintenance	Lots of overspray and fog, so booth maintenance is high.	Less overspray and fog; booth maintenance is low.	Least overspray and fog. Booth maintenance slightly better than airless spray.
5. Pattern Adjustment	Yes	No	Yes
6. Tip Plugging	Virtually none	Yes	Better than airless spray because larger tips are used.
7. Equipment Life	Very long because, fluid pressure is low.	High tip wear and shorter pump life because very fluid pressure required.	Less tip wear and longer pump life because substantially lower fluid pressure than airless spray.
8. Energy Consumption	Poor efficiency of atomizing liquid, high air consumption.	Good efficiency of atomizing liquid.	Most efficient way of atomizing liquid. Very low air consumption.
9. Noise	Very noisy	Quiet	Quiet
10. Emission Level	High	Low	Low

[a]The transfer efficiency is measured at Graco laboratory with a stationary gun spraying at the moving targets hung on the conveyor. The targets are 6 inches wide and have a 12 inch center-to-center distance. Therefore, the maximum transfer efficiency for non-electrostatic spray equipment is 50 percent. This test is a modified version of the ASTM D3451-19 test procedure.

manufacturers claim that electrostatic applications have a relatively short pay back period, because the transfer efficiency is extremely high, and thus much less coating is needed. Moreover, the cost of a more basic manual electrostatic spray system is approximately $3,100 per gun for retrofit application of an air spray system. This cost assumes that all existing equipment such as solvent hoses, pumps, hangers, and spray booths will not require modifications. The payback period using this retrofit system would be relatively short. Figure 3-3 depicts a manual electrostatic spray gun. One user did note safety problems associated with some electrostatic systems (i.e., reciprocating disc system).[6,7] However, another supplier remarked that there are sufficient safety features built into these systems, but he acknowledged that operators can defeat the purpose of the safety features if the systems are not grounded properly.[7]

3.3 ADD-ON CONTROL TECHNIQUES

Add-on control techniques include, primarily, thermal or catalytic incineration and carbon adsorption. The practice of VOC incineration has been evaluated by EPA, by the Illinois EPA, and by the South Coast AQMD.[10] All of these agencies have found conventional or catalytic incineration to be technically feasible; however, its use has not been demonstrated in the wood furniture industry because of high costs involved. Control efficiencies of incineration in other industries is about 90 percent.[13] Because no incinerator systems are currently being used in the wood furniture industry for controlling VOC emissions, the technology would have to be borrowed from other coating industries. In addition, it is not economically feasible to capture and duct VOC emissions from sources such as roll coaters, spray booths, ovens, and conveyor lines to an add-on control device.

The use of incinerators in the wood furniture industry presents several problems. The main problem results from high exhaust flow rates from a spray booth and low VOC concentrations. Air flow rates range from 140 to 1400 m^3/min, whereas the VOC concentrations are usually less than 200 ppm.[10] This results in an exhaust stream that has a low heat content, and supplemental fuel would be required. Another problem stems from the fact that exhaust streams from the different

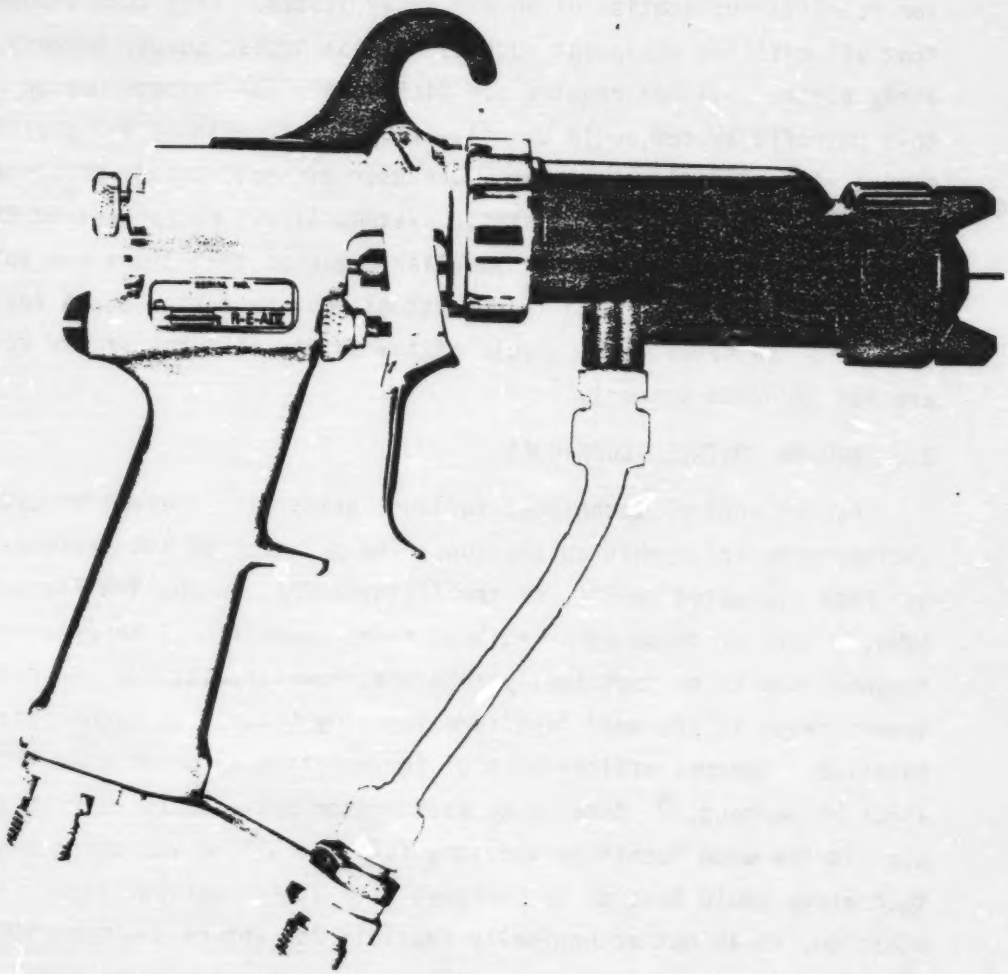

Figure 3-3. Manual electrostatic spray gun (Reference 3-12).

spray booths cannot be ducted together because they could be incompatible, and spontaneous combustion might occur. Therefore, each spray booth would require its own incinerator, which would be more expensive than having one large incinerator. Another fire hazard results from the nitrocellulose solids present in the coatings settling out in the ducts. A buildup of nitrocellulose could cause an explosion or a fire.

Carbon adsorption has also been evaluated.[10] Control efficiencies for carbon adsorbers have exceeded 90 percent in other industries. Because adsorption of a very dilute VOC stream presents technical problems, however, it is preferred over incineration only when the solvent can be recovered and reused. One of the most significant technical problems concerns the high amount of solids that escape existing particulate controls (e.g., air filters or water filters). These solids reduce the life of the carbon bed and the collection efficiency of a carbon system. To eliminate this problem it may be necessary to precede the unit with an additional particulate control device such as a fabric filter. This increases the cost of such a system and discourages implementation by wood coating facilities. Many wood furniture coating solvents are water-soluble, so steam-stripping of the carbon bed produces dilute VOC solutions in water. Because the proportions of solvents that are recovered by steam-stripping would be different from the proportions used in the coatings and would have to be processed further for reuse, carbon adsorption does not seem to be a feasible control method.

3.4 CONCLUSIONS

Reasonably available means for reducing VOC emissions from wood furniture coating operations consists of an application method at least equivalent to air-assisted airless spray equipment. Air-assisted airless spray equipment would result in a 30 to 35 percent VOC emission reduction and a corresponding decrease in coating usage.[8,9]

3.4 REFERENCES

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13. Control Technique Guidelines for the Control of Volatile Organic Emissions from Wood Furniture Coating. Draft. U.S. Environmental Protection Agency, Emission Standards and Engineering Division. Research Triangle Park, NC. April 1979.

4.0 ENVIRONMENTAL ANALYSIS OF RACT

This section presents the environmental and energy impacts associated with applying reasonably available control technology (RACT) to the wood furniture coating industry. The environmental analysis consists of primary impacts from air and water pollution and solid waste since there are no secondary impacts associated with RACT. Primary impacts are considered to be those impacts directly associated with application of RACT, while secondary impacts are only indirectly associated with application of RACT.

4.1 REASONABLY AVAILABLE CONTROL TECHNOLOGY

Reasonably available control technology for wood coating facilities located in Shelby County, Tennessee, includes VOC emission reductions for spray booths through implementation of control spray equipment or other means, such as utilizing low VOC coatings. These implementations must result in emission reductions of at least 33 percent over current conventional spray methods. An air-assisted airless spray system has been presented for both model plants. Implementing this system reduces VOC emissions as shown in Table 4-1 and Table 4-2 for model plants A and B, respectively. In addition, RACT for minimizing VOC emissions from all process lines and from cleanup and waste handling practices (e.g., spray coating, roll coating, etc.) includes good housekeeping and operational practices including, but not limited to, the following:

- o covering containers of coating when not in use,
- o proper use and disposal of VOC-containing materials,
- o weekly visual inspection of pumps,
- o repair of all leaking equipment.

4.2 AIR POLLUTION IMPACTS

The uncontrolled VOC emissions from the model plants (described in Section 2.4) engaged in wood furniture coating are 243.5 megagrams per year (Mg/yr) (268.4 tons/yr) for Model Plant A and 487 Mg/yr (536.8 tons/yr) for Model Plant B. These uncontrolled emissions can be reduced

TABLE 4-1. VOC EMISSIONS
DUE TO RACT FOR MODEL PLANT A

	Before RACT[a]	After RACT
	Air Spray	Air-Assisted Airless
Coatings and Solvents used per year, liters (gallons)[b]		
Stain	18,925 (5,000)	12,680 (3,350)
Sealer	56,775 (15,000)	38,039 (10,050)
Topcoat Lacquer	37,850 (10,000)	25,360 (6,700)
Varnish	56,775 (15,000)	38,039 (10,050)
Washcoat	30,280 (8,000)	20,288 (5,360)
Toner	26,495 (7,000)	17,752 (4,690)
Thinner	22,710 (6,000)	15,216 (4,020)
Other Solvents	90,840 (24,000)	60,863 (16,080)
Total	340,650 (90,000)	228,236 (60,300)
VOC emissions, Mg/yr (tons/year)[c]		
Stain	12.9 (14.3)	8.6 (9.5)
Sealer	39.4 (43.5)	26.3 (29.1)
Topcoat Lacquer	25.3 (28)	17 (18.8)
Varnish	30.6 (33.8)	20.5 (22.6)
Washcoat	20.3 (22.4)	13.6 (15)
Toner	19.6 (21.7)	13.1 (14.5)
Thinner	19.8 (21.9)	13.3 (14.7)
Other Solvents	74.9 (82.8)	50.2 (55.5)
Total VOC emissions (tons/yr)	242.9 (268.4)	162.6 (179.7)
Percent VOC emission reduction	--	33

Table 4-1. VOC EMISSIONS
DUE TO RACT FOR MODEL PLANT A
(Concluded)

Footnotes:

[a] Model Plant A consists of 6 spray booths that are assumed to use conventional air spray application before implementation of RACT.

[b] Coating usage estimates based on information from Reference 1. Usage estimated for six spray booths using conventional air spray systems. Coating and solvent usage is reduced by 33 percent using air-assisted airless spray.

[c] VOC emission estimates for each coating are calculated by multiplying the following average VOC contents (based on References 1 and 3) by the liters (gallons) of coatings used, converted to megagrams (tons) of VOC per year:

Coating	Average VOC Content (kg/liter)	(lb/gal)
1. Stain	0.68	5.7
2. Sealer	0.69	5.8
3. Topcoat		
Lacquer	0.67	5.6
Varnish	0.54	4.5
4. Washcoat	0.67	5.6
5. Toner	0.74	6.2
6. Thinner	0.87	7.3
7. Other Solvents (e.g., acetone, methanol, VM&P, etc.	0.83	6.9

Example calculation for VOC emissions from stain coating using air-assisted airless equipment:

$$12{,}680 \text{ liters/yr} \times 0.68 \text{ Kg/liter} \times \frac{1 \text{ Mg}}{1{,}000 \text{ kg}} = 8.6 \text{ Mg/yr.}$$

TABLE 4-2. VOC EMISSIONS
DUE TO RACT FOR MODEL PLANT B.

	Before RACT[a]	After Ract
	Air Spray	Air-Assisted Airless
Coatings and solvents used per year, liters (gallons)[b]		
Stain	37,850 (10,000)	25,360 (6,700)
Sealer	113,550 (30,000)	76,078 (20,100)
Topcoat		
Lacquer	75,700 (20,000)	50,719 (13,400)
Varnish	113,550 (30,000)	76,078 (20,100)
Washcoat	60,560 (16,000)	40,575 (10,720)
Toner	52,990 (14,000)	35,503 (9,380)
Thinner	45,420 (12,000)	30,431 (8,040)
Other Solvents	181,680 (48,000)	121,726 (32,160)
Total	681,300 (180,000)	456,471 ((120,600)
Coating and solvent VOC emissions per year, Mg/yr (tons/year)[c]		
Stain	25.9 (28.6)	17.2 (19)
Sealer	78.7 (87)	52.7 (58.2)
Topcoat		
Lacquer	50.7 (56)	34.0 (37.6)
Varnish	61.2 (67.6)	40.9 (45.2)
VOC emissions (tons/yr)		
Washcoat	40.5 (44.8)	27.1 (30)
Toner	39.3 (43.4)	26.2 (29)
Thinner	39.6 (43.8)	26.6 (29.4)
Other solvents	149.9 (165.6)	100 ((111)
Total VOC emissions (tons/yr)	485.8 (536.8)	325.2 ((359.4)
Percent VOC emission reduction	--	33

Table 4-2. VOC EMISSIONS
DUE TO RACT FOR MODEL PLANT B
(Concluded)

Footnotes:

[a] Model Plant B consists of 12 spray booths that are assumed to use conventional air spray application before implementation of RACT.

[b] Estimates based on information from Reference 1. Usage estimated for 12 spray booths using conventional air spray systems. Coating and solvent usage is reduced by 33 percent using air-assisted airless spray.

[c] VOC emission estimates for each coating calculated by multiplying average VOC contents, kg/l (lb/gal), listed in Table 4-1, footnote (c), by the liters (gallons) of coating used, converted to megagrams (tons).

Example calculation for VOC emissions from stain coating using air-assisted, airless equipment:

$$25{,}360 \text{ liters/yr} \times 0.68 \text{ Kg/liter} \times \frac{1 \text{ Mg}}{1{,}000 \text{ kg}} = 17.2 \text{ Mg/yr.}$$

by 33 percent with the use of an air-assisted airless spray system. Therefore, VOC emissions from Model Plant A will be reduced to 163 Mg/yr (179.7 tons/yr) using an air-assisted airless system. Similarly, VOC emissions from Model Plant B will be reduced to 326 Mg/yr (359.4 tons/yr) using an air-assisted airless system. Tables 4-1 and 4-2 present VOC emissions from implementation of RACT for Model Plants A and B, respectively, for each coating and solvent.

4.3 WATER POLLUTION IMPACTS

Implementation of RACT for wood furniture coating facilities located in Shelby County is not expected to increase the amount of wastewater generated. Therefore, RACT is not expected to have a significant impact on water pollution.

4.4 SOLID WASTE IMPACTS

The use of air-assisted airless systems will result in a slight positive solid waste impact. As a result of using this alternative spray system, the amount of solid waste generated will actually decrease due to an increase in transfer efficiency. This reduces the amount of solid particles released to the environment.

4.5 ENERGY IMPACTS

The use of air-assisted airless spray systems is not expected to increase the energy required to apply the coatings. In fact, air-assisted airless systems require about 15 to 20 percent less energy (e.g., fuel, electricity) than conventional air spray systems. Airflow through spray booths using air-assisted airless systems is about 12 acfm compared to 16-20 acfm for conventional air spray systems.[2]

4.5 REFERENCES

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5.0 CONTROL COST ANALYSIS OF RACT

The costs of implementing reasonably available control technology (RACT) for controlling emissions of VOC from wood furniture coating facilities are presented in this chapter. Estimates of capital costs and annualized costs for controlling VOC emissions from wood furniture coating are presented in Sections 5.1 and 5.2. The cost effectiveness of RACT is discussed in Section 5.3. All costs presented in this document are based on April 1985 dollars.

5.1 CAPITAL COSTS

The capital costs for implementing RACT are based on the purchase and retrofit installation of air-assisted airless spray equipment. Total installed capital costs per spray booth obtained from equipment manufacturers would be $2,200 for air-assisted airless equipment.[1] Capital costs for heated air-assisted airless equipment would be slightly higher than cold air-assisted airless equipment, but heated equipment would not achieve significantly better emissions reduction; therefore, the cost of heated air-assisted airless equipment was not analyzed.[1] Capital costs given in Table 5-1 present the estimated costs per spray booth to retrofit conventional air spray equipment with this alternate system. Costs to retrofit spray booths with electrostatic equipment are given in Appendix C. RACT costs to control VOC emissions from roll coating lines (i.e., lids on containers, cleanup, and repair practices) are not included because costs for good housekeeping practices and leak detection and repair are expected to be minimal. Since plants may already be implementing such practices using existing employees, no additional labor is expected to be required.

5.2 ANNUALIZED COSTS

Annualized costs for implementing RACT are based on the purchase and operation of the spray equipment specified in Section 5.1. Annualized costs per application system for Model Plants A and B are presented in Table 5-2. The net annualized costs include a capital recovery cost and recovered product credit (paint savings) for each system. All other annualized costs are estimated to be the same as conventional air spray equipment. Therefore, no additional retrofit costs were assumed.

Table 5-1. CAPITAL AND ANNUALIZED COSTS PER BOOTH TO RETROFIT CONVENTIONAL AIR SPRAY EQUIPMENT[1]
(April 1985 dollars)

		Cold Air-Assisted Airless
A.	Capital	
1.	Equipment	$2,200[a]
2.	Other	b
B.	Annualized	
	Direct Operating	
1.	Operating Labor	c
2.	Operating Materials	c
3.	Maintenance	c
4.	Replacement Parts	c
5.	Utilities	d
	Indirect Operating	
1.	Overhead	c
2.	Tax, Insurance, Administration	c
3.	Capital Recovery Cost	360

[a] Includes equipment costs such as purchase and installation of booster pump to existing central pump system; cost of spray gun (one spray gun per booth) ($425); flue regulator ($350); air transformer ($250).

[b] All other capital costs such as installation costs (start-up, construction, etc.,) are assumed to be the same as conventional air spray equipment; therefore, no additional costs would be incurred.

[c] Annualized costs are estimated to be the same as conventional equipment; therefore, no additional costs would be incurred.

[d] Utilities are estimated to be 15 to 20 percent less for air-assisted equipment because less airflow is required. No credit for reduced utility costs is estimated.

Table 5-2. ANNUALIZED RETROFIT COSTS
FOR MODEL PLANTS A AND B
FOR ALTERNATIVE APPLICATION EQUIPMENT[a]
(April 1985 dollars)

Cost Item		ALTERNATIVE EQUIPMENT	
		Model Plant[b]	Cold Air-Assisted Airless
1.	Capital Recovery Cost[c]	A	2,200
		B	4,400
2.	Recovered Product Credits[d]	A	(150,000)
		B	(300,000)
	Net Annualized Costs	A	(147,800)
		B	(295,600)

(xx) denotes cost savings

[a] Reference 1.

[b] Model Plant A consists of six spray booths, and Model Plant B consists of 12 spray booths.

[c] Capital Recovery Cost = Capital Cost x Capital Recovery Factor (CRF). CRF based on 10 percent interest and 10-year life = 0.163.

Capital recovery cost is based on capital costs of $2,200 for cold air-assisted airless. *(Example for cold air-assisted airless, Model Plant A = ($2,200/booth) x (6 booths) x (0.163) = $2,200/yr.)

[d] Product recovery value is based on annual savings in coating and solvent usage as a result of switching from conventional spray equipment to alternative equipment that achieves higher transfer efficiencies. Assumes that paint savings is a function of the relative differences in transfer efficiency between conventional air spray and alternative equipment. Calculated from Table 5-3, assuming incremental transfer efficiencies of 33 percent for air-assisted airless equipment. (Example calculation: retrofit cost for cold air-assisted airless, Model Plant A,

	Before RACT Cost		Incremental Transfer Efficiency
=	- $448,590	x	0.33
=	- $148,000		
≃	- $150,000		

TABLE 5-3. ANNUAL USAGE AND COST OF COATINGS AND SOLVENT FOR AIR SPRAY EQUIPMENT

Coating/Solvent	Usage[a] (gal/yr)	Cost[b] $/gal	Total Cost ($)
Spray Stain	5,000	6.88	34,400
Sealer	15,000	6.85	102,750
Topcoat			
Lacquer	10,000	6.80	68,000
Varnish	15,000	6.00	90,000
Washcoat (thinned lacquer)	8,000	5.66	45,280
Toner (pigmented stain)	7,000	6.88	48,160
Thinner	6,000	2.00	12,000
Other Solvents	24,000	2.00	48,000
Total	90,000	---	448,590

[a] Estimates based on information from Reference 2; usage estimated for six spray booths using conventional air spray equipment.

[b] Cost information from Reference 3, April 1985 dollars. Costs per gallon for thinner and other solvents are maximum costs and, therefore, represent a worst case scenario.

Recovered product credits are included, assuming that annual savings in coating and solvent usage are realized as a result of switching from conventional air spray equipment to alternative equipment. Table 5-3 presents total annual usage and cost of coatings and solvent for conventional air spray equipment for Model Plant A. For Model Blant B, the usage and cost of coatings and solvent would be doubled. Net annualized savings associated with retrofitting conventional air spray equipment would be about $150,000 per year for Model Plant A and about $300,000 per year for Model Plant B.

5.3 COST EFFECTIVENESS

The cost effectiveness of implementing RACT represents the net annualized costs (or savings) per VOC emission reduction achieved. The net annualized savings are presented in Table 5-2. VOC emissions reductions (per model plant) associated with RACT are calculated from Tables 4-1 and 4-2. The resulting VOC emission reductions and cost effectiveness associated with switching from conventional air spray to alternative equipment are presented in Table 5-4. The cost effectiveness is estimated as a savings of $1,840/Mg ($1,670/ton) for air-assisted airless equipment.

TABLE 5-4. VOC EMISSION REDUCTION AND COST EFFECTIVENESS OF IMPLEMENTING RACT FOR MODEL PLANTS A AND B
(April 1985 dollars)

Application Equipment	Air Assisted Airless
Model Plant A	
Net annualized costs[a]	147,800
VOC emission reduction, Mg/yr (tons/yr)[b]	80.3 (88.7)
Cost effectiveness (savings), $/Mg ($/ton)[c]	1,840 (1,670)
Model Plant B	
Net annualized costs[a]	295,600
VOC emission reduction, Mg/yr (tons/yr)[d]	161 (177)
Cost effectiveness (savings), $/Mg ($/ton)[c]	1,840 (1,670)

[a]From Table 5-2. Net annualized costs are cost savings.

[b]From Table 4-1.

[c]VOC emission reduction divided by net annualized savings from Table 5-2. Cost-effectiveness numbers are savings per Mg (ton) of VOC emissions reduced.

[d]From Table 4-2.

5.4 REFERENCES

1. Telecon. Cole, D., Pacific Environmental Services, Inc., with Travis, W., GRACO. April 17, 1985. Retrofit costs for airless and air-assisted airless systems.

2. VOC Emissions Inventory Update, 1984. Memphis-Shelby County Health Department, Pollution Control Section.

3. Telecon. Cole, D., Pacific Environmental Services, Inc., with Dodson, R.F., The Davis Company, Memphis, TN, April 18, 1985.

APPENDIX A

MODEL REGULATION

APPENDIX A. MODEL REGULATION

1200-3-18-__. Wood Furniture Coating

(1) For the purpose of this rule, the following definitions apply:

(a) "Air-assisted airless spray application" means a method of coating application in which the coating is atomized in variable-shaped patterns (e.g., conical or oval) through an airless fluid nozzle, and atomization is assisted by pressurized air cap.

(b) "Airless spray application" means a method of coating application in which the coating is atomized in a conical-shaped pattern through an airless fluid nozzle.

(c) "Application area" means the area where the coating is applied by spraying, dipping, or rollcoating (flowcoating) techniques.

(d) "Coating" means topcoat, sealer, filler, washcoat, toner, stain, or other material that is applied directly to the wood part or furniture.

(e) "Transfer efficiency" means the ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids used, expressed as a percentage.

(f) "Wood furniture" means surface-coated room furnishings that include cabinets, tables, chairs, beds, sofas, shutters, art objects, and any other coated furnishings made of solid wood and/or wood composition and/or simulated wood material.

(2) This rule will apply, in accordance with 1200-3-18.__ - (3), to the application area(s), flash off area(s), or other process and storage areas of wood furniture coating operations.

(3) (a) Wood furniture coating material containing VOC shall be applied using either:

(i) Air-assisted airless spray application methods for all coating steps or

(ii) Methods that achieve equivalent or better VOC emission reductions than the methods specified in subparagraph (3)(a)(i).

(b) For the purpose of achieving equivalent or better VOC emission reductions as specified in subparagraph (3)(a)(ii):

(i) The following emission reductions expressed as percentages shall be considered to reflect incremental transfer efficiencies between conventional air spray systems and other application methods, unless the owner/operator demonstrates an actual measured transfer efficiency to calculate actual emission reductions:

Application Methods	VOC Emission Reduction (%)
Air-assisted airless spray	33
Electrostatic air spray	46
Electrostatic disk or bell atomizer	61
Dip and drain	66
Rollercoat, wipe or brush	71

(ii) Owners and/or operators may use low VOC content coatings and/or high transfer efficiency application methods.

(iii) To calculate equivalent VOC emission reductions, owners and/or operators shall compare the VOC content of actual

materials used in each coating step with the baseline VOC content for such step. Baseline VOC content for each coating step shall be based on a review of plant records of coatings used during the preceding 12-month period. All equivalency calculations shall use deposited solids as the operable comparison parameter.

(c) Owners and/or operators shall comply with, but shall not be limited to, the following housekeeping and operation. procedures to minimize VOC emissions from cleanup and waste-handling practices or process equipment leaks:

(i) Use of closed containers for disposal of cloth or paper, which is impregnated with solvent-containing VOC, used for surface preparation cleanup and paint removal, unless such practice constitutes a fire hazard.

(ii) Weekly visual inspection of pumps in VOC service for indications liquids dripping from the pump seals.

(iii) If any equipment in VOC service appears to be leaking on the basis of sight, smell, or sound, a readily visible identification shall be attached to the leaking equipment and the leak repaired as soon as practicable within 15 calendar days. The identification may be removed upon repair.

(4) The VOC content of coatings subject to the provisions of this rule shall be determined by the method specified in 1200-3-18.-44, "Determination of Volatile Content of Surface Coatings."

Authority: T.C.A. 54-3412. Administrative History. Original rule certified (effective date of rule).

APPENDIX B

ENFORCEMENT ASPECTS

B.0 ENFORCEMENT ASPECTS

B.1 COMPLIANCE DETERMINATION

Determining compliance with the recommended regulation will require the following:

1. Visual inspection of each facility to determine the presence of air-assisted airless spray systems or methods that achieve equivalent or better emission reduction.

2. Visual inspection of the facility to check equipment leaks from pumps, valves, etc., and to ensure proper use and disposal of VOC containing materials.

3. To demonstrate equivalent means of emission reduction (e.g., reducing VOC content of coatings), purchase records of coating materials (showing VOC content) shall be inspected and compared with records over the 12-month period prior to the effective date of this rule to ensure that coating materials conform to the standards. The conformance of coating materials to the standard can be determined by analysis as described in Rule 1200-3-18.44.

B.2 TRANSFER EFFICIENCY

There is no standard means of demonstrating actual transfer efficiencies of spray application systems. One vendor has measured transfer efficiencies of airless and air-assisted airless systems in a laboratory using a modified ASTM test procedure (D-3451-19); however, the maximum transfer efficiency for non-electrostatic spray equipment was found to be 50 percent. Therefore, this method would not be practicable to measure transfer efficiencies of greater than 50 percent. Furthermore, vendors can modify test methods to yield desired transfer efficiencies.

B.3 EQUIVALENT CONTROL

The incremental transfer efficiency (e.g., the difference between the transfer efficiency for a conventional spray system and the transfer efficiency for an air-assisted airless system) is the best criterion to use as a measure of potential emission reductions. For example, if an owner or operator elects to reduce the VOC content of coating material

applied instead of installing air-assisted airless systems, then he must demonstrate that the difference in VOC content of coating material is at least equivalent to the incremental transfer efficiency between conventional air spray and air-assisted airless spray (an increment of 33 percent). Therefore, the owner or operator must reduce the VOC content of coating material by 33 percent or more by reformulation. As described above, plant records of coatings purchased can be inspected to ensure compliance with this alternative means of emission reduction.

APPENDIX C

RETROFIT COSTS FOR ELECTROSTATIC SPRAY EQUIPMENT

APPENDIX C - RETROFIT COSTS FOR ELECTROSTATIC SPRAY EQUIPMENT

As discussed in Section 3.2, electrostatic spray application systems are more difficult to assemble and require a greater capital expense than air, airless, or air-assisted airless systems. However, the retrofit cost associated with one electrostatic system (a manual system using an air spray electrostatic gun) is $3,100, which assumes no additional costs for pumps, redesign of spray booths, etc.[1] This system could be used to reduce VOC emissions from spray coating lines instead of RACT specified in Section 4.1 (i.e., airless, air-assisted spray systems or systems that achieve comparable emission reduction or better).

Tables C-1 through C-3 present the capital and annualized costs associated with two automated electrostatic systems. The costs presented in Table C-1 represent an automated spray system with one spray nozzle that may achieve between 65 and 95 percent transfer efficiency, whereas the costs presented in Tables C-2 and C-3 represent an automated, computerized system with four spray nozzles or "bells" that may achieve up to 95 percent transfer efficiency.

TABLE C-1. CAPITAL AND ANNUALIZED COSTS FOR MANUAL ELECTROSTATIC SPRAY EQUIPMENT[a,b] (April 1985 dollars)

Cost Item	Cost
Capital Cost	
Equipment	$45,000
Installation and Startup	6,750
TOTAL CAPITAL COST	51,750
Annualized Cost	
Capital Recovery Cost[c]	8,440
Maintenance[d]	5,175
TOTAL ANNUALIZED COST	13,615

[a]Reference 1.

[b]Costs are for retrofitting one spray booth.

[c]Capital Recovery Cost = Capital Cost x Capital Recovery Factor,

where: Capital Cost = $51,750
Capital Recovery Factor (CRF) is calculated as follows:

$$\frac{i\,(1+i)^n}{(1+i)^n - 1} = 0.163,$$

where i = 10 percent annual interest

n = 10-year equipment life

[d]Assume 10% of capital cost per year.

TABLE C-2. CAPITAL COST FOR AUTOMATED, COMPUTERIZED ELECTROSTATIC SPRAY EQUIPMENT*
(Retrofit Costs, Arpil 1985 dollars)

Cost Item	Cost
Spray booth renovation with 4 bells	77,800
Furniture hangers and hanger holders	30,000
Pumps, lines, etc.	13,000
Computer system with in-house software	19,500
Contingencies	15,500
TOTAL CAPITAL COSTS	155,800

*Reference 2.

TABLE C-3. ANNUALIZED COSTS FOR AUTOMATED, COMPUTERIZED ELECTROSTATIC SPRAY EQUIPMENT[a]
(April 1985 Dollars)

Cost Item	Cost
Capital Recovery Cost[b]	25,360
Maintenance	3,000
TOTAL ANNUALIZED COSTS	28,360

[a]Reference 2.

[b]Capital Recovery Cost = Capital Cost x CRF,

where: Capital Cost = $155,800 (from Table C-2), and
CRF = 0.163, as calculated in Table C-1.

REFERENCES

1. Telecon. Sink, M., Pacific Environmental Services, Inc., with Travis, W., GRACO, May 16, 1985.

2. Telecon. Cole, D., Pacific Environmental Services, Inc., with Travis, W., GRACO, April 17, 1985.

3. Telecon. Sink, M., Pacific Environmental Services, Inc., with Maddox, D., Stanley Furniture Corp., April 17, 1985.